Performance of the Marx generator for repetitive applications

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***Abstract* - We designed a Marx generator for repetitive applications. The Marx generator has 25 stages. Each stage was constructed 4 door knob ceramic capacitors and a ball spark gap switch. We used the inductor charging method for higher repetitive operation. The designed maximum output voltage of the Marx generator is 1 MV at open circuit condition. The overall size of the Marx generator is 150 cm in length and 60 cm in diameter. We tested the Marx generator at different load conditions. We present the results of the test and characterize the Marx generator.**

I. Introduction

Marx generator is widely used in high voltage applications, such as X-ray machines or electromagnetic wave radiators. For these applications, Marx generator is as compact and repetitive as possible [1] [2]. We designed a repetitive Marx generator, whose size is small considering the maximum output voltage capability.

We present the design features of the Marx generator and discussed the several kinds of performance of it.

II. Design Consideration

Marx generator generally consists of several capacitors and switches, as shown in fig. 1. Each capacitor charged by a high voltage power supply though charging resistors.

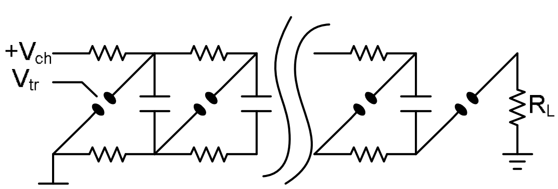

Fig. 1. The basic Marx generator circuit.

When the first switch is triggered, the second switch feels almost double of the charging voltage so that the second switch is turned on because the voltage is larger then the hold off voltage of the switch. This process is going on until the all switches are closed, and the all capacitors is connected in series.

Since the charging voltage, however, is distributed not only to the charging capacitors, but also to the intrinsic and stray capacitance of the switch as shown in Fig. 2, the voltage multiplication across the switch gap is lower than the theoretical value. The voltage difference between the gaps of the second switch is given by

$$\Delta V = V_{ch}\left(1 + \frac{C_s}{C_s + C_{sw}}\right) \qquad (2)$$

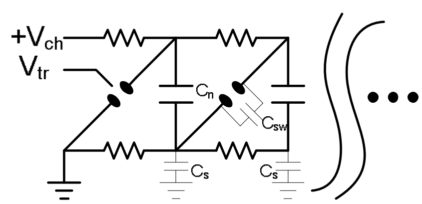

Figure 2. The capacitive components in a Marx generator.

Therefore, the switch capacitance is much smaller then the stray capacitance between the ground wall and metal structure for connection of capacitors, resistors, and switches.

When Marx generator is discharged, it is simply approximated as an equivalent RLC circuit. When the equivalent inductance and the equivalent capacitance of a Marx generator are L_{eq} and C_{eq} , respectively, the equivalent impedance of the Marx generator is calculated from the equation:

$$Z_M = \sqrt{C_{eq} / L_{eq}} \qquad (3)$$

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III. System Description

Fig. 3 is 3D view of the Marx generator. The details of the Marx generator were reported in ref. [3]. We used 100 TDK ceramic capacitors of 2.1 nF and 50 kV. Each stage consists of 4 capacitors which are connected by a half circular aluminum guide. We arranged the capacitors in zigzag form. The zigzag configuration helps to minimize the length of the Marx generator since the required insulation distance between stages is intrinsically obtained as the length of capacitor. The number of stages is 25 in order to obtain the output voltage we need. The spark gap switches are axially installed in a tube which provides a different gas environment from outside, which make possible gas flowing to reduce the recovery time of the switch. The stainless steel tank is filled with high pressure SF_6 or nitrogen gas for insulation.

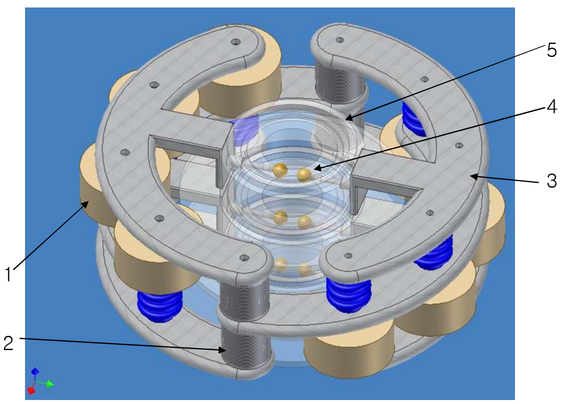

Fig. 3. 3D view of the Marx generator. 1: capacitor, 2: charging inductor, 3: guiding connector, 4: spark gap switch, 5: Switch tube

With the aligned spark gap switch configuration also enhance the triggering of the Marx generator, because UV light generated by the early discharged switch help next switch invoke self breakdown. We used additional capacitors at first two stages to increase the voltage difference at the first two spark gaps, which enlarge operating pressure range of the Marx generator.

Fig. 4 is the photograph of the Marx generator. The overall dimension of the Marx generator is 1.5 m in height and 60 cm in diameter. A D-dot probe is installed near the end of the Marx generator for voltage measurement. The derivative voltage signals are integrated by a self made RC passive integrator.

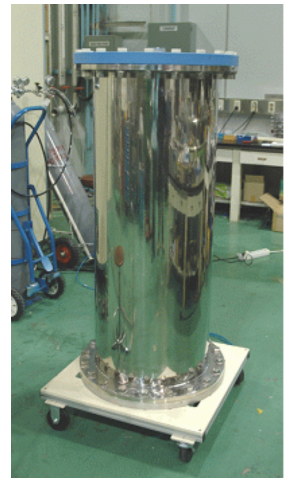

Fig. 4. Photograph of the Marx generator.

IV. Modeling

Fig. 5 shows one stage of the Marx generator for PSPICE modeling. C1 is the capacitance of one stage. C2 is the stray capacitance between the stage and the ground metal wall. We modeled that the spark gap switch has a capacitance C3. L3 and R3 are stage to stage stray inductance and series resistance, respectively, including spark gap inductance. R1 and L1 are charging inductor's coil resistance and self inductance, respectively. R2 and L2 are isolation inductor's coil resistance and self inductance, respectively. We modeled entire stages by chaining this one stage.

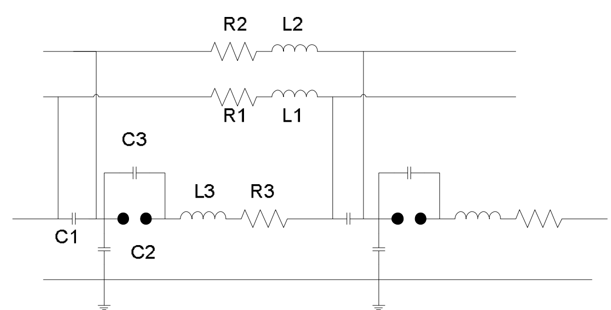

Fig. 5. the Marx generator.

Fig. 6 is a modeled result of the Marx generator for resistive load. When the charging voltage is 20 kV, the output voltage at load of 100 Ω is expected over 200 kV for over 40 ns.

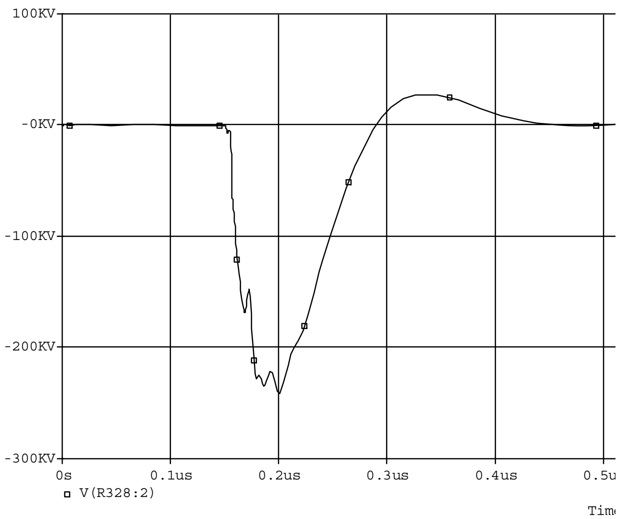

Fig. 6. Modeled result of the Marx generator.

charging power supply (General Atomics). The Marx generator was successfully operated at the burst mode.

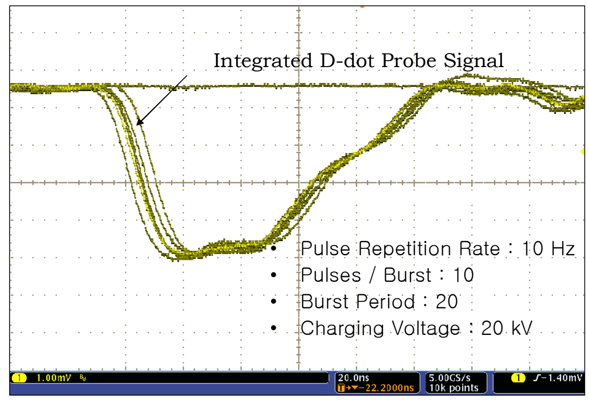

Fig. 7. Modeled result of the Marx generator.

V. Performance Test

Fig. 7 is a typical resistor load test result. The resistor is a aqueous solution of NaCl, which resistance measured 99 Ω. The aqueous solution load works as a voltage divider. The blue waveform is aqueous solution high voltage divider signal, and the yellow waveform is the integrated signal of the d-dot probe. The charging voltage of the Marx generator is 20 kV. The pulse width of output voltage waveform is larger then 40 ns.

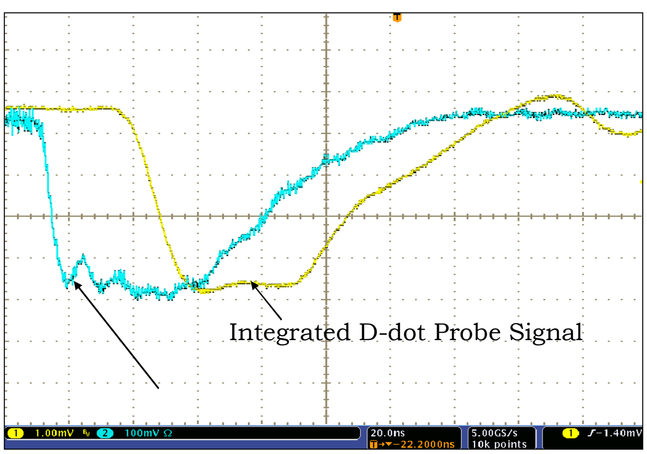

Fig. 7. 100 W aqueous resistor load test result of the Marx generator.

Fig. 8 shows the repetitive operation performance of the Marx generator. The load is also 100 W aqueous solution of NaCl. The Marx generator was charged by a 12 kJ/s capacitor

VI. Summary

We developed a Marx generator which has feature of compactness and repetitiveness. The test results shows that the Marx generator has pulse width over 40 ns and low jitter performance at burst mode operation with impedance around 99 Ω. We expect that the Marx generator can be used successfully in several high voltage pulse applications.

Reference

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